

BANDWIDTH LIMITING / NEW STANDARD

International EESS Wideband Downlink Workshop

March 25-27, 2003

Orlando, U.S.

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Chairman ECSS RF & Modulation Panel

BANDWIDTH LIMITING / NEW STANDARD

- X-Band Constraints and Issues
- Today's Baseline EES Downlink System Design
- Mitigation Methods to Reduce Potential X-Band Congestion
- Restriction of X-Band to 'Small' Users
- Standard Bandwidth-Efficient Modulations
- 8-PSK TCM Modulation Performances
- CCSDS 401(2.4.18) Recommendation
- ECSS E50-05
- State-of-the-Art Technology
- Conclusion

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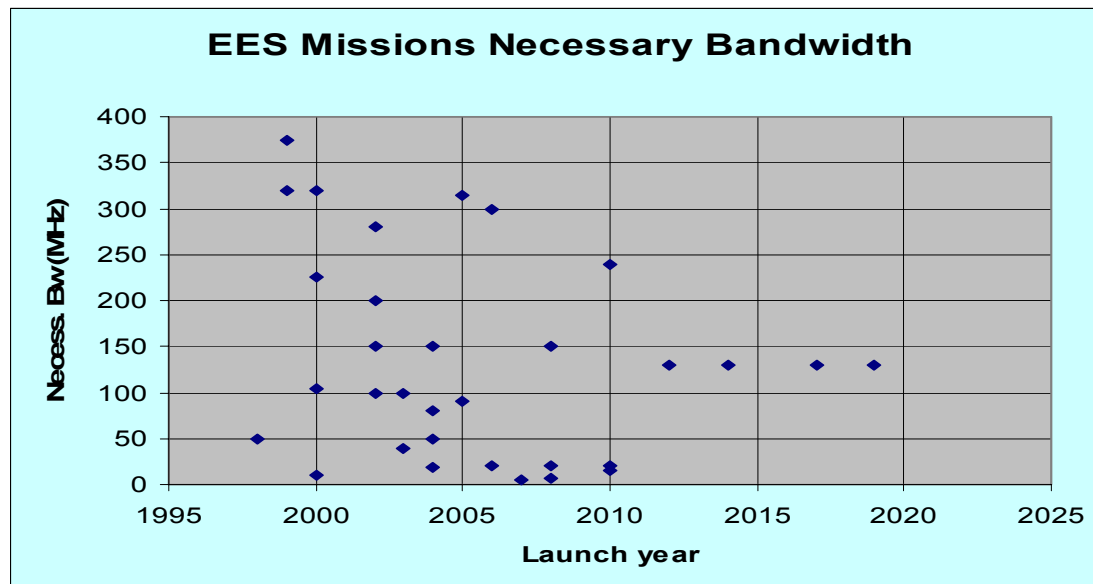
X-Band (8025-8400 MHz) Constraints and Issues

1. X-band 375 MHz bandwidth cannot satisfy future high capacity missions

Currently flying ≤ 300 Mbps data rate

Plans up to 1.2 Gbps

2. Density of EES satellites in low Earth polar orbit is increasing



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X-Band (8025-8400 MHz) Constraints & Issues

3. PFD limit on the Earth surface in the neighboring deep space band 8400 – 8450 MHz:
-255 dBW/m²/Hz (SFCG Rec 14-1)
Spectrum filtering + coordination
4. Broadcast mode to be avoided (SFCG Rec 14-3R4).
Transmission only in view of Earth station

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Today's Baseline EES Downlink System Design

- Almost all spacecraft operate in the 8025 – 8400 MHz band (alternative is the 2GHz S-band for very low data rates)
- Some spacecraft operate in broadcast mode
- Modulation methods are not bandwidth-efficient.
Most popular schemes ranked on bandwidth efficiency:
 - BPSK
 - QPSK
 - Filtered OQPSK
- Unfiltered transmissions potentially harmful to deep space band

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Mitigation Methods to Reduce Potential X-Band Congestion

- Avoid broadcast mode
- Adopt bandwidth-efficient modulation scheme 8 PSK TCM
CCSDS and ECSS new recommendations and standards
- Move wide-bandwidth missions to higher frequency band
25.5 – 27 GHz band
- Restrict X-band to ‘small’ users
Small users: necessary bandwidth < tbd MHz
- Band segmentation

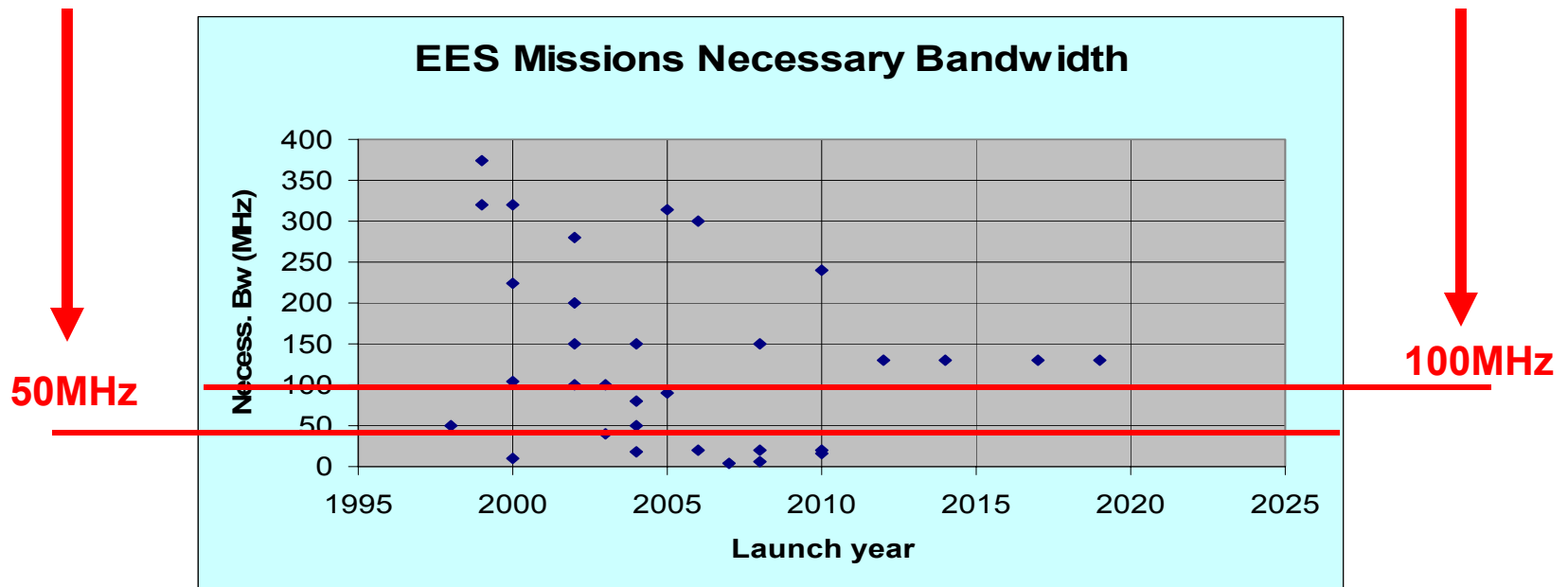
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Restriction of X-band to 'small' users

Maximum bandwidth of 50 MHz or 100 MHz has been considered.

66% of missions go to Ka

53% of missions go to Ka



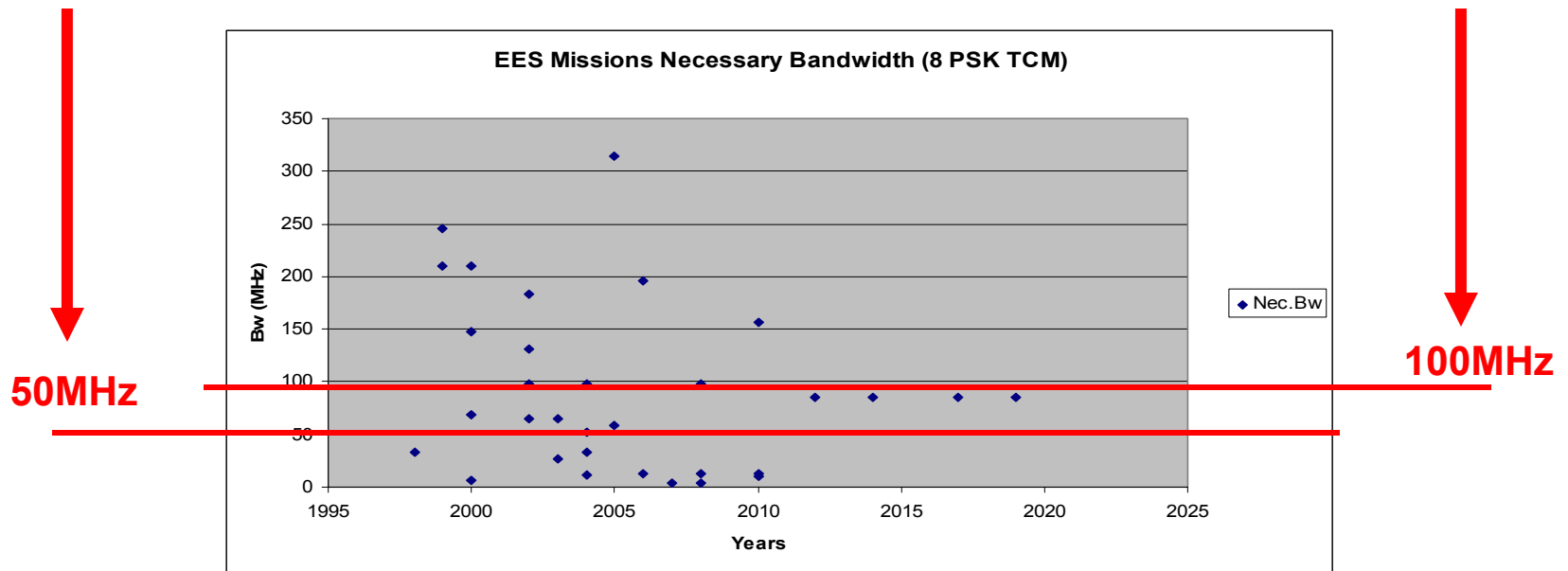
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Restriction of X-band to 'small' users

Use of 8 PSK TCM instead of (O)QPSK with RS. *BW reduced by 35%.*

66% of missions go to Ka

28% of missions go to Ka



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Restriction of X-band to 'small' users

Issue of segmentation of the 8025-8400 MHz band

Proposals submitted in the past, e.g.:

- 7 channels @ 50 MHz

- 2 guardbands @ 12.5 MHz at the edges

Main problem is decreased efficiency in spectrum utilization.

Main advantage is more structured coordination.

May be a way to accommodate broadcast mode missions.

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Restriction of X-band to 'small' users

Summary

- Actual risks of interference to be assessed
- If interference risk considered too high, maximum bandwidth for X-band to be defined
- Bandwidth-efficient modulations to be widely adopted
- Wide-band users to move to the 25.5 – 27 GHz band
- Broadcast mode to be reserved to Ka-band or maybe accommodated in a restricted part of the band.
- Ka-band requires:
 - Ground infrastructure investment
 - Coordination on key parameters for proper cross-support

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Standard Bw-Efficient Modulations (1)

Focus on:

- Spectral compactness
- Link performances
- Implementation complexity
- Feasibility (especially onboard) with state-of-the-art technology
- Cost – benefit issue

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Standard Bw-Efficient Modulations (2)

New scheme 4-Dimensional 8-PSK Trellis-Coded Modulation (4D 8PSK TCM) adopted by **CCSDS** and by **ECSS**

CCSDS: Consultative Committee for Space Data Systems

Members: *ASI/BNSC/CSA/CNES/DLR/ESA/INPE/NASA/NASDA/RSA*

Observers and associates:

Some 25 agencies and laboratories, 100 industries

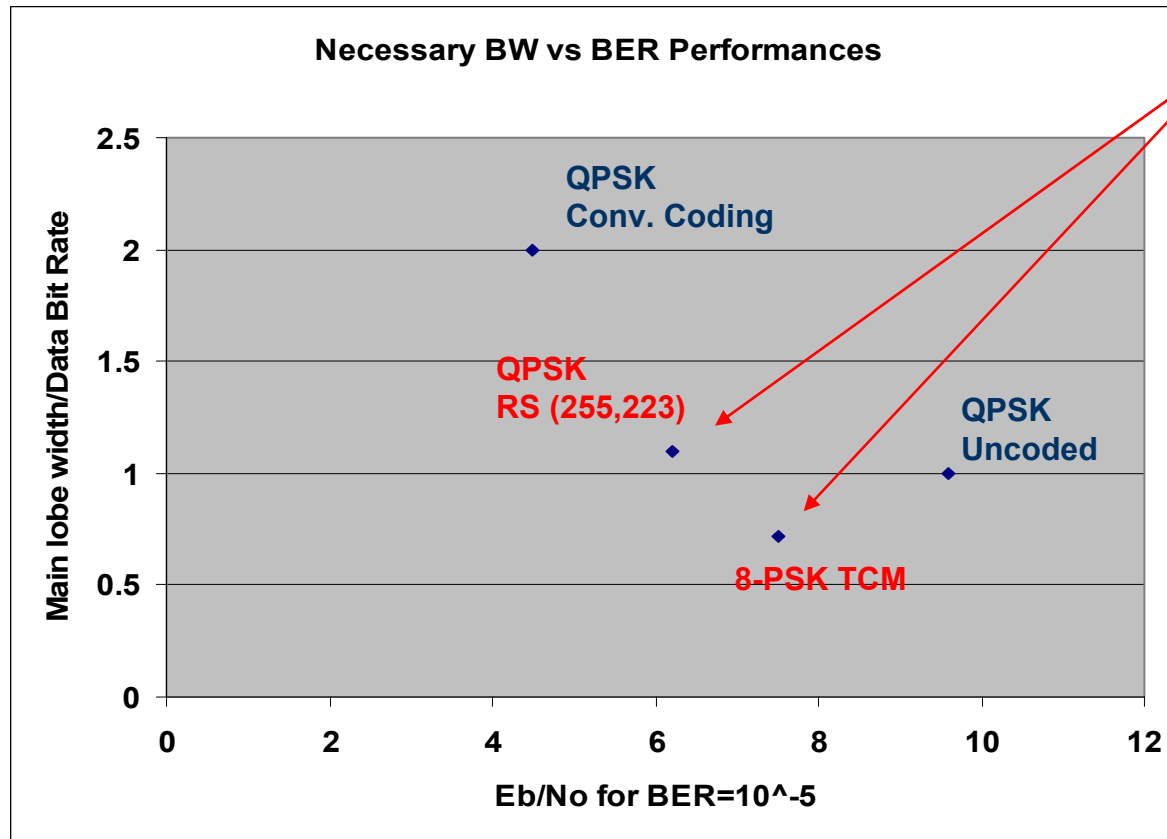
<http://www.ccsds.org/>

ECSS: European Cooperation for Space Standardization

Members:

European agencies ASI/BNSC/CNES/DLR/ESA and industries

<http://www.ecss.nl/>

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**8-PSK TCM
brings 35%
increased BW
compactness at
the cost of only
1.3dB on link
performance**

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8-PSK TCM Modulation Performances (2)

8-PSK TCM selection criteria:

- 8-PSK for bandwidth compactness
Channel Symbol Rate $R_c = R_b/2.5$
- Trellis Coding for optimum link performances
Reduced onboard EIRP for a given Earth station G/T
- SRRC filtering ($\alpha = 0.35$) for minimum OOB emissions
SFCG Rec 21-2

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CCSDS 401(2.4.18) Recommendation:

1. *(1) that a mission planning to use conventional modulation methods which have an occupied bandwidth exceeding that permitted by the SFCG for the 8025-8400 MHz band, use 4D 8PSK TCM, provided that in no case shall the occupied bandwidth of said mission exceed that permitted by the SFCG;*
2. *(2) that whenever the occupied bandwidth permitted by SFCG in the 8025-8400 MHz band cannot be met, agencies migrate to the 25.5-27 GHz band.*

This recommendation lays the foundations for the use of bandwidth-efficient modulations at X-band and for the move of 'big users' to Ka band. The maximum allowable occupied bandwidth remains to be settled. It is one of the objects of this workshop to help preparing SFCG's regulatory work.

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ECSS E50-05A Space Engineering – Radio Frequency & Modulation, section 6.2.1:

The ECSS standard requires the use of either 8PSK TCM or Filtered-OQPSK in the 8025-8400 MHz band whenever the symbol rate exceeds 2Ms/s.

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State-of-the-Art Technology (1)

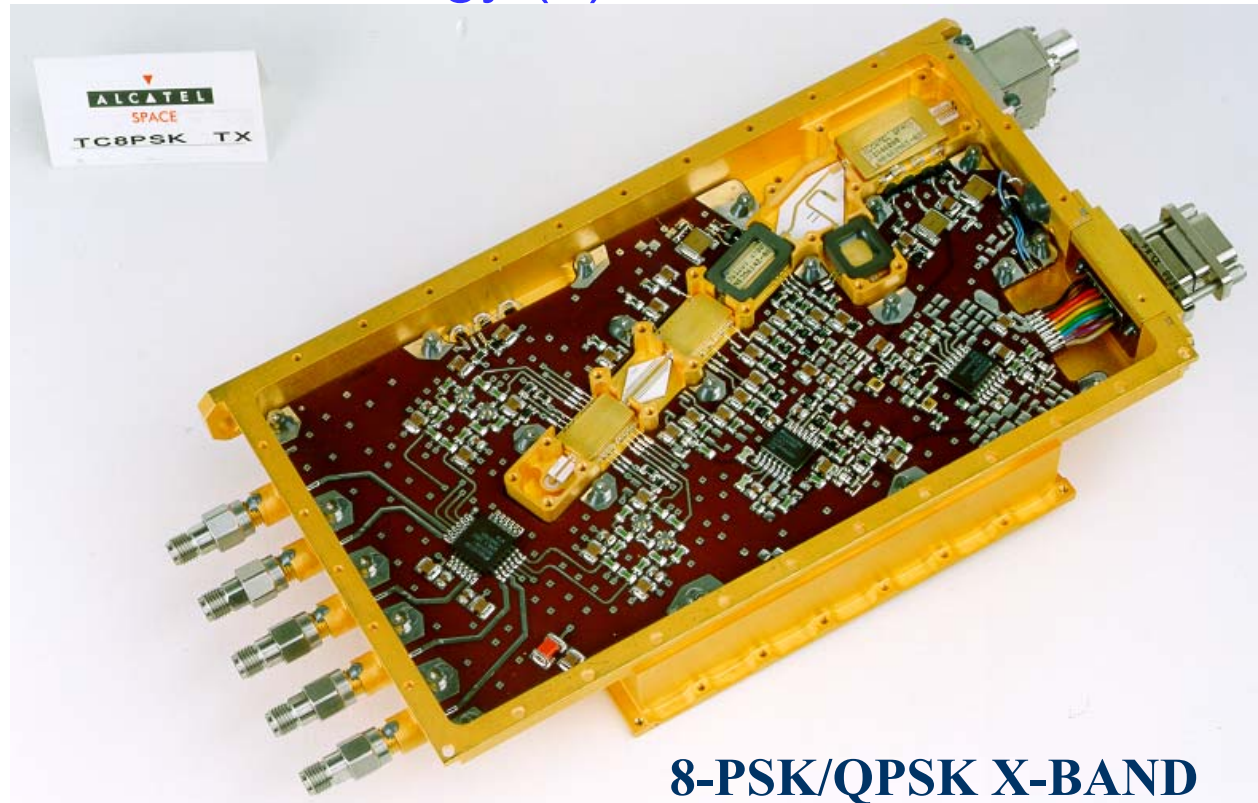
8-PSK/QPSK X-BAND TRANSMITTER

- 8025-8400 MHz
- RF Power 6W
- Up to 155.5 Mbps
- 622 Mbps capacity at 8 GHz (4 transmitters)
- TCM 5/6 or 2/3 8PSK
QPSK optional
- RS 239/255 trellis
coding



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State-of-the-Art Technology (2)



**8-PSK/QPSK X-BAND
TRANSMITTER RF
Board**

BW LIMITING / NEW STD**State-of-the-Art Technology (3)**

Parameters	Performance 8PSK	Performance QPSK
Output power	p to 6 W / 10 W option	Up to 22 W (ext. HPA)
Useful data rate	p to 155 Mbps (67 Mbauds)	Up to 140 Mbps (75 Mbauds) 8025 to 8400 MHz
Frequency		+/-13 ppm
Stability	025 to 8400 MHz	9 dB (255, 238) RS coding
Eb/No @ BER = 10⁻⁹	/-13 ppm	

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State-of-the-Art Technology (4)

EARTH STATION DEMODULATOR



- QPSK/8PSK modulations
- NRZ/SRRC 0.35/ SRRC 0.5
- Differential decoding in QPSK configuration
- Viterbi decoding (TCM), De-Interleaving, Reed-Solomon decoding, Descrambling in 8PSK
- BER degradation: < 1.4 dB (QPSK and 8PSK TCM2/3)
< 1.6 dB (8PSK TCM5/6)

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Conclusions

- **Improve understanding of EES interference potential in the 8025-8400 MHz band**
- **Implement methods for ‘smart’ use of the band:**
 - Compact modulations
 - Coordination
- **Limit user maximum bandwidth if deemed effective**
- **Prepare Ka-band ground infrastructure for upcoming wide-band users**